Identification of individual Carnaby's Cockatoos *Calyptorhynchus latirostris* from distinctive plumage markings

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ABSTRACT

This study determined methods for identifying individual Carnaby's Cockatoo *Calyptorhynchus latirostris* using natural variations in markings, to assist future research and management. Photographs of wild and captive cockatoos and museum specimens were studied and a variety of useful identification characteristics were found. These included marks on subterminal tail panels, yellowish colouration, upper mandible markings, atypical white feathers, white panels on undertail coverts and grey areas in the ear covert patches of females. A combination of distinctive marks could sometimes be used to identify individuals. Distinctive markings may be short term and useful until the next moult, or longer term and maintained over years. Females provided more identifying marks than males, with 28.6% of preserved adult female tails having black spots and/or bars in their white tail panels compared to 5.0% of adult males, and 53.1% of immature females compared to 12.5% of immature males. The tails of immature *C. latirostris* were more commonly heavily marked, compared to adults, suggesting that marks, where present, are gradually lost over successive moults. This was confirmed by observations of heavily marked tails re-growing feathers without markings and with analysis of pentosidine concentration in skin to age six museum specimens. A gradual loss of spots and bars in subterminal tail panels in some *C. latirostris* may reflect the evolutionary history of this endangered endemic Western Australian species.

Key words: Carnaby's Cockatoo, Calyptorhynchus latirostris, field identification, individual recognition, plumage, distinctive markings

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Introduction

Many wildlife studies require the identification of individuals. For birds this usually involves fitting leg bands/rings, patagial tags or nasal nares; however, these methods require the capture of individuals. For species where capture is difficult or not possible, it is necessary to rely on the observation of distinctive natural markings, physical characteristics or vocalisations. Identification based on distinctive features is a non-invasive technique that overcomes concerns regarding the dangers, costs and ethics approvals associated with trapping wild adult birds (Zdenek 2012), particularly endangered species.

Photo identification methods have been successfully used for marine species such as whales (Katona and Whitehead 1981) and dolphins (Hillman *et al.* 2003) that have unique markings on fins or tails such as pigmentation, barnacles, scarring or injuries. Terrestrial examples are fewer, but include spots on Northern Quolls *Dasyurus hallucatus* (Hohnen *et al.* 2013) and Cheetahs *Acinonyx jubatus* (Kelly 2001). Individuals from a number of bird species have also been identified by variations in markings. Bretagnolle et al. (1998) used variations in black markings on the heads of Ospreys *Pandion haliaetus* to identify individuals, and found that markings changed only slightly over two years. Munn (2006) used photo-identification of Hyacinth Macaws *Anodorhynchus hyacinthinus,* utilising lines, cracks and scars on their mandibles, in addition to dots around the eye-ring. Munn thought the latter markings were more permanent than mandibles scars. Other examples include chest markings of African Penguins *Spheniscus demersus* (Sherley *et al.* 2010), plumage patterns and crest shape of Andean Condors *Vultur gryphus* (Ríos-Uzeda and Wallace 2007) and plumage patterns of male Ruffs *Philomachus pugnax* (Lank and Dale 2001).

Individual members of the Cockatoo family (Cacatuidae) have also been identified from variations in markings. For some species of black cockatoo, the greatest individual variation in plumage characteristics occurs on the tail feathers. For example, juveniles and females of the Red-tailed Black-Cockatoo *Calyptorhynchus banksii* and Glossy Black-Cockatoo *C. lathami* have distinctive bars on their tail feathers (Courtney 1986a). The extent of these bars reduces with age, particularly in males, and their configuration can be used to estimate the age of an individual and to sometimes identify individuals

at least until the next moult (Garnett *et al*. 1999; Murdoch 2008). Variable yellow head plumage has also been used, together with tail barring, to identify female *C. lathami* individuals (Garnett *et al*. 1999; Murdoch 2008). Zdeneck (2012) found preliminary evidence that differences in mandible shape could be used to identify individual Palm Cockatoos *Probosciger aterrimus*.

These efforts to enable individual identification have expanded knowledge of the various study species. Individual identification techniques allow researchers to monitor populations and establish survival rates, flock composition and stability, social behaviour, recruitment, age at first reproduction, movements during breeding and non-breeding seasons, and breeding behaviour. Such information is helpful for assessing the conservation status of species and determining appropriate recovery actions, as are required for *C. latirostris*. This species is listed as endangered by the Western Australian and Commonwealth Governments and internationally by IUCN (2014), and is the subject of a recovery plan (Department of Environment and Conservation 2013). The plan states the need to conduct research to inform management of *C. latirostris*, including the generation of more knowledge on movements, food plants and roosting behaviour, to gain a better understanding of the way the species uses resources across its range. The ability to identify individuals from natural markings would assist in achieving this goal.

Stainless steel patagial tags, numbered stainless steel leg bands (Saunders 1982; 1988; Saunders *et al.* 2011b; Dawson and Saunders 2014) and satellite tracking devices (Groom *et al*. 2013, 2014) have been used on some populations of *C. latirostris* to identify individuals for research purposes, and have provided important information on the ecology and behaviour of *C. latirostris*. This research has been conducted by a number of organisations, particularly CSIRO and Department of Parks and Wildlife (Saunders 1982; Saunders and Ingram 1998; Department of Conservation and Environment 2012; Saunders *et al.* 2014a). Temporary markings applied in the form of colour to the white panels of tail feathers have also been used to identify individuals and to encourage sightings (McMahon 2006; Groom *et al*. 2013), however, the colour fades within a couple of months and so is only useful for short periods.

Only a small proportion of *C. latirostris* have been marked to allow individual recognition by humans. Patagial tags are no longer fitted to this species as they may increase the risk of predation by Wedge-tail Eagles *Aquila audax* (Saunders 1982; 1988), and banding adult birds is difficult as it involves trapping and the potential for injury. As a result, banding is performed on nestlings of several populations throughout the species' range (Saunders *et al.* 2013), and on injured wild birds brought in for rehabilitation (Dawson and Saunders 2014). Unfortunately, bands have their limitations, as reading band numbers on wild adults is difficult (Saunders and Ingram 1998; Saunders *et al*. 2011a), and is typically only done by researchers with access to expensive photographic equipment or telescopes, although Dawson and Saunders (2014) did challenge the wider conservation community to attempt photographic identification of individuals.

At present, the difficulties associated with reading band numbers, the lack of permanency of coloured tail feathers and the small numbers of marked *C. latirostris*, have restricted both community engagement and the ability of researchers to identify and understand the behaviour of individual birds (Dawson and Saunders 2014; Groom *et al.* 2014).The recovery plan for the species specifies the need for greater engagement of the Western Australian community to generate information about *C. latirostris*, and identification of individual birds and reports of their activities will help this to occur (Dawson and Saunders 2014). Current descriptions of the species such as that found in Higgins (1999) do not indicate the presence of variations in natural plumage markings that could enable individual identification. In this paper we examine the variation in plumage patterns on *C. latirostris*, particularly the subterminal tail panels and ear covert patches, and assess their prevalence in relation to age and sex. We raise the possibility of using a combination of natural markings to identify individuals in the wild in order to provide more information on the ecology of the species.

Methods

Study area and study species

Calyptorhynchus latirostris is a large parrot found only in the south-west of Western Australia. There has been a significant decrease in the range and abundance of the species since the 1940s as a result of loss of breeding and foraging habitat due to broadscale clearing of native vegetation (Saunders 1990; Saunders and Ingram 1998; Department of Environment and Conservation 2013). In addition, the species is subject to a number of other threats, including disease, extreme climate events, collisions with motor vehicles and competition with other species for breeding hollows (Saunders *et al*. 2011a,b; 2014a,b).

C. latirostris is dull-black in colour, with older feathers appearing a lighter brown black. Feathers are narrowly edged with off-white (Higgins 1999). The tail has a large subterminal panel of white (Fig.1), hence the former common name of Short-billed White-tailed Black Cockatoo (Saunders 1974). A "little black speckling" is sometimes present in the white subterminal panels of adults and juveniles, and some individuals have a cream blotch on one or more undertail coverts (Higgins 1999). Physical characteristics can be used to determine the sex and age (adult vs immature) of individuals. Mandibles of adult males are black, while those of females are light grey, or bone coloured (Forshaw 1969). Both sexes have whitish ear covert patches, but they are smaller and duller on males. In addition, mature males have pink periophthalmic rings while those of females are grey.

C. latirostris follow the same morphological changes with sexual maturity as recorded in the closely related Yellow-tailed Black Cockatoo *C. funereus*. In male *C. funereus* the upper mandible darkens by two years old and the lower mandible by four years old (Courtney 1986b). The periophthalmic rings of males turn pink as they reach

Figure 1. A male *C. latirostris* (right) displays to a female.

sexual maturity at about four years of age (Courtney 1986b; Jupp 2000). In contrast, female *C. latirostris* do not develop obvious external physical changes with age or sexual maturity. Immature birds spend at least their first year with their parents and can be distinguished by their clumsy landing, walking and food handling abilities. They often perch with a hunched appearance while begging. Parents feed their juvenile offspring, however, this behaviour also occurs between members of mated pairs.

During this study distinctive plumage and upper mandible markings were recorded to identify individual wild *C. latirostris* at several Perth metropolitan areas, captive cockatoos in rehabilitation centres and museum specimens held at the Western Australian Museum (WAM) and CSIRO's Australian National Wildlife Collection (ANWC).

Terminology

A comprehensive description of the physical characteristics of *C. latirostris* may be found in Higgins (1999), and we follow the terminology used in that publication. The 12 tail feathers of *C. latirostris* were numbered on each side of the midline as T1 to T6 from the centre outwards. The two central tail feathers (T1) are black. All other tail feathers typically have a subterminal white panel on the inner (broader side of the feather) and outer web, with the exception of T6, which has a black outer web (Higgins 1999).

White panels on undertail coverts (UTC) that were present on one side of the feather were described as a "1" for that feather, or described as a "2" if present on both sides of the feather (Fig. 2a). UTC scores in Supplementary Data have been presented from the base of the UTC towards the distal end of the tail.

Museum collections

The tails of preserved specimens of *C. latirostris* were inspected for markings on the white subterminal tail panels to determine their prevalence and usefulness for identifying individuals in the field. Only marks that occurred on both the dorsal and ventral sides of feathers were considered as a positive for that specimen. Spotting on T2, and spots close to the base of subterminal panels of all tail feathers,

Figure 2a. Distinctive markings on the tails of female *C. latirostris* in the Perth metropolitan area. A: No white panels on the under tail coverts (UTC). B: 3, 2, 1, 1 pattern of panels on the UTC and black spots in the tail panes. C: Female with unusually extensive white panels on the UTC. D: Heavy white fringing on chest feathers, one white panel on UTC and barred tail.

were not scored as positive for distinctive marks, as these were almost ubiquitous, and therefore not distinctive. Ambiguous markings including pale grey marks and other dirt smudges were often observed and were not included in the analysis. The maturity and sex of specimens were recorded to show correlations that might exist with the presence and degree of tail markings. Sexing and aging were performed by museum curators based on notes and observations of sex-distinctive colouration, together with an examination of the gonads of most specimens.

During 1970, *C. latirostris* were shot in pine plantations at Gnangara and Somerville (now the Perth suburbs of Murdoch, Winthrop and Booragoon) and in pine plantations and native forest to the east of Mundaring and Sawyers Valley. These birds were collected under permits appropriate to the time, during research into

Figure 2b. Distinctive markings on the tails of female *C. latirostris* in the Perth metropolitan area. A: 2, 1 pattern of panels on the under tail coverts and half-bars in the tail panels. B: Immature with barring in the tail panels, being fed.

the ecology and demography of the species. Each month from April to July 1970 a sample was collected, with individuals shot at random until the 10th adult male was collected (Saunders, in litt.). The tails of 89 birds (24 adult males, 26 adult females, 13 immature males, 20 immature females and six which had no age or sex ascribed to them) (Appendix 1) were preserved in a fanned position and lodged with the ANWC in Canberra. The upper and lower faces of each fanned tail were photographed with the specimen number and a scale in mm, and the photographs examined for individual variation.

In addition to preserved fanned tails, 125 dry specimens of *C. latirostris*, both entire bodies and tails only, were examined at WAM. They consisted of 16 adult males, 23 males whose maturity was not known and three immature males. In addition there were 37 adult females, 17 females whose maturity was not known and 12 immature females. No sex was ascribed to 15 specimens (Appendix 1).These specimens were collected throughout the species' distribution in south west Western Australia. Sixty three of these specimens were from Hopetoun and Munglinup, collected after a heatwave killed at least 208 birds in January 2010 (Saunders *et al.* 2011b). Specimens were photographed and black markings in the white subterminal panels recorded as above, together with the presence of white panels on the undertail coverts.

In addition, a sample of skin was collected from the patagium of six WAM specimens to examine if a relationship exists between the extent of tail marking and age. The skin sample was analysed for the concentration of pentosidine which is known to accumulate incrementally over time and can be used to estimate the age of each bird (Le Souëf 2012). This was matched to subterminal panel marks.

A T-Test was performed using Excel to determine the probability that adult and immature *C. latirostris* have the same frequency of subterminal tail panel markings. All preserved museum specimens were included.

Field observations of a breeding population

A semi-resident breeding population of approximately 30 *C. latirostris* was observed and photographed on a daily basis at a private property near Mundaring over four years, and all unusual markings noted. This group is referred to hereafter as the "Mundaring" population. Due to the ability to observe the same individuals regularly, the usefulness of less obvious characteristics could be explored for individual identification, together with the longevity of some markings.

This population permitted nest site fidelity and other breeding behaviours to be followed over consecutive years. Nine artificial nests constructed from wood were provided to assist breeding, and installed in living Marri *Corymbia calophylla* trees. *C. latirostris* using these artificial hollows as well as natural hollows in the surrounding area were regularly observed and photographed, often as they arrived or departed their nest hollow or drank from water provided in bird baths. *C. latirostris* were photographed using Canon 7D and 7D Mark II cameras with a 200 mm, 70-300 mm L series lens, or a 400 mm L series lens.

The ear covert patches of both male and female *C. latirostris* vary in brightness and in size within the respective sexes, but these differences were typically not distinctive enough and were not used for identification purposes in this study.

Table 1: The percentage of museum specimens from WAM and ANWC that have subterminal tail panel markings, represented by sex and maturity. * nk = not known. Numbers next to key show sample size for that group followed by the number of specimens with subterminal tail panel markings.

		WAM	% WAM	ANWC	% ANWC	Totals ALL	% spots/bars
Adult Female	Total	37		26		63	
	Spots/bars	12	32.4%	6	23.1%	18	**28.6%**
Female maturity nk*	Total	17				17	
	Spots/bars	7	41.2%			7	**41.2%**
Adult Male	Total	16		24		40	
	Spots/bars	0	0.0%	2	8.3%	2	**5.0%**
Male maturity nk*	Total	23				23	
	Spots/bars	1	4.3%			1	**4.3%**
Immature Female	Total	12		20		32	
	Spots/bars	6	50.0%	11	55.0%	17	**53.1%**
Immature Male	Total	3		13		16	
	Spots/bars	0	0.0%	2	15.4%	2	**12.5%**
Unkown sex	Total	15		6		21	
	Spots/bars	7	46.7%	0	0.0%	7	**33.3%**

Field observations of flocks in the Perth metropolitan area

Field observations were gathered while following flocks of *C. latirostris* in the Perth metropolitan area, with a focus on subterminal tail panel markings. This permitted the prevalence of re-sighting individuals that were not regularly returning to a nest to be determined, together with the prevalence of re-growing moulted tail feathers with and without marks (Appendix 2).

The study region was bounded by Guilderton in the north, Keysbrook in the south, and the Darling Scarp in the east, and was centred on a ~30km radius of the Perth central business district (Groom 2015). In 2012 and 2013 a total of 173 flock follows of *C. latirostris* was undertaken ranging from seven minutes to 10 hours and 28 minutes (average 3 hours 30 minutes) resulting in over 540 hours following flocks. The flock follows were assisted by the signal from study birds fitted with satellite tracking devices (Groom *et al.* 2014). Birds were readily observable and distinctive markings on their tails were photographed using a Canon EOS 500D or EOS 7D camera with a 100-400 mm f4.5-5.6 L IS USM lens. All photographs in the field were taken between February and September in 2012 and 2013.

Results

Distinctive markings were observed on a minority of specimens, however, female *C. latirostris* displayed more distinctive markings that permitted the identification of individuals than did males. The pale mandible and brighter ear covert patches of females made individual markings more obvious than on the dark mandible and duller ear covert patches of males. In addition, females exhibited a higher prevalence of subterminal tail panel markings (Table 1). In the Mundaring population, 13 individuals out of approximately 30 regular visitors could be identified, with 12 being female. The one male that could be identified had a bald area on his head (see below).

Table 2: Distinctive markings found on *C. latirostris* in the Perth metropolitan area, and their ease of use, uniqueness and likely potential to be used as a long-term characteristic. DC = different combinations occur. Y = yes, N = no. UTC = undertail coverts. ? = not known. Long term markings are present for more than one breeding season or moult.

Marking	Long term	Easy to observe	Requires high resolution photos	Common	Unique
Atypical white markings on head and/or body	Y	Y	N	N	Y
Coloured ear coverts: females	Y	Y	N	N	DC
Black spots/bars on white subterminal tail panels	?	Y	N	Y	Y
Yellow tail feathers	?	Y	N	N	DC
Baldness	Y	Y	N	N	N
Thick black marks on mandibles: females	Y	Y	N	?	?
White panels on UTC	?	Y	N	Y	No, DC
Thin black marks on mandibles: females	?	N	Y	?	?

A summary of distinctive markings considered during this study is shown in Table 2 and compares the different markings for longevity and difficulty to observe in the field. Some markings require use in combination to identify individuals.

Distinctive markings on the tail

Black spots, half bars and bars were observed in the subterminal tail panels of wild and preserved *C. latirostris*. Markings ranged from readily observed bars or half bars on multiple feathers (Figs. 2aD and 2b), to a few small spots on one or two feathers (Fig 2aB). A total of 214 preserved specimens were examined for these subterminal tail panel markings at WAM and the ANWC. Immature birds had comparatively higher rates of subterminal tail panel markings than adults, and markings were heavier than those of adults. In addition, markings occurred on significantly more adult females than adult males (Table 1). T-test results indicate that there was 95% confidence that the frequency of tail markings differed between the immature and adult specimens (WAM adult frequency = 0.23: n = 53, CSIRO adult frequency = 0.16: n = 50. WAM immature frequency = 0.40: n = 15, CSIRO immature frequency = 0.39: n = 33). That is, there was only a 5% probability that immature and adult *C. latirostris* are equally likely to possess tail markings. However, it should be noted that some specimens recorded as adult females may be in fact immature females, since these are difficult to distinguish in the absence of behavioural cues, and intact ovaries and oviducts are not always present due to the state of decomposition of some bodies prior to preservation.

Other useful variations in the markings on tail feathers include a white outer web of T6 (typically black), black extending up the rachis, and thick black edges to the outer margins of outer webs. Variations also occurred in the shape of the distal margins of subterminal panels, with some birds having a straight division, and others being angled, curved or irregular.

Variation also occurred in subterminal tail panel colouration. Two females from the Mundaring population were photographed with cream or yellow tail feathers on one side of the tail (Fig. 3B and C). In both cases the females also had black spots or half bars on the yellow feathers. One of these females lost both the fine spots and pale yellow colouration on three tail feathers in a subsequent moult. The other female grew a yellow tail feather with a half-bar over the period she was observed, with the yellow colouration being most intense when the feather was new. Some WAM specimens appeared to have yellowish subterminal panels, but this was difficult to confirm due to the possibility of storage artefacts. In addition, three WAM specimens, two from Hopetoun and one from Cockburn, had a greyish brown subterminal tail panel on the inner web of one tail feather in each case.

Markings on T6 subterminal tail panels are most useful as they can be observed when the bird is perched, resting or feeding. Markings on other tail feathers are best observed when the bird fans its tail just prior to landing, or during flight. Often only a glimpse is possible and so photography is useful for capturing images that can be compared subsequently.

Field observations following flocks in the urban and peri-urban landscape in the Perth metropolitan area identified 43 individuals with distinctive tail markings that were photographed on at least one occasion, of which 14 were photographed on more than one occasion (Appendix 2). The longest time between sightings was 138 days. Individuals with distinctive tail markings, and particularly those with the most extensive barring, were observed undertaking behaviours consistent with being juveniles – begging calls, being fed or generally clumsy.

To assess the longevity of markings on subterminal tail panels particular note was taken of re-growing tail feathers of individuals whose old feathers featured markings. At least six of the 43 wild birds photographed with tail markings appeared to be re-growing tail feathers that lacked markings. Although limited sightings and photographs provided few opportunities to confirm this, nonetheless no markings could be seen on the visible portions of re-growing or new feathers (blacker, non-scruffy tip and often wider than old feathers). However, in one example from the Mundaring population a re-growing feather had a half bar (Fig. 3B).

The pentosidine concentration in skin samples from six WAM *C. latirostris* specimens with spots or bars in the subterminal panels indicated the specimens ranged from 10 months to 8 years old (Table 3). The heaviest tail markings occurred on immature birds aged one year or younger, however, these results are preliminary and further testing is necessary for a definitive analysis.

Distinctive markings on the head

Females - Colour of ear covert patches.

Unusual colouration of female ear covert patches may involve both ear coverts on an individual, or only one. This is readily observed in the field. Examples of female *C. latirostris* in the Mundaring population include both ear covert patches grey, one ear covert patch having a grey bar at the top, the other bright (Fig. 4A, B) and one ear covert mottled grey, the other bright. A female with two grey ear covert patches was observed in the Mundaring population for four years, suggesting that this characteristic is stable over time. The female had additional identifying characteristics of white panels on her UTC. Two other females had "old gold" ear covert patches and edges to their feathers on the upper parts of their bodies (Fig. 3A). The two females could be distinguished from each other by panels on the UTC, and one of these was photographed over two years.

Females - Dark lines on the mandibles.

Two females in the Mundaring population had mandible markings that were photographed over several years. One female had a thick dark line on the right hand side of her upper mandible, running from the base of the upper mandible to the tip. This individual was photographed over three years, and the mark was stable over this time. This distinctive marking was readily observed with binoculars

Figure 3. Variation in markings and colouration of *C. latirostris* in the Perth metropolitan area. A: Female with "old gold" ear covert patches and edges to feathers. B: Female with a yellowish tail feather with spots and half-bars. C: Female with three yellowish tail feathers with spots. D: Unusual markings on tail panel.

and by eye. Another female was photographed over two years with a thin "Y" shape on the left hand side of her upper mandible, requiring good quality binoculars or high quality photographs to distinguish. The two females nested consecutively in the same hollow during consecutive years.

Both sexes - White feathers on the head and upper body.

At least four C. *latirostris* have been photographed with atypical regions of white on the head and, in some cases, also on the body. The authors photographed two examples of this on a male and a female. The male, at Kaarakin Black Cockatoo Conservation Centre, had white feathers emerging from the top of the upper mandible, creating a "v" shape when observed face-on (Fig. 5A). The wild female was photographed at The Vines, a suburb in the Perth metropolitan area, and had patches of white on the back of the head (Fig. 5C). Other observers in the Perth metropolitan area have photographed at least two wild males with large regions of white plumage. These males had mostly white heads and white scattered down their backs and fronts (Fig. 5B and D). They were photographed only two months apart in 2009, and had distinctly different patterns of black and white. The male in Fig. 5B was photographed repeatedly in 2007, 2009 and 2011, and was readily recognisable by the pattern formed by black and white feathers. These characteristics are likely to be stable over time, and are the most readily observed feature in the field. However, they are uncommon.

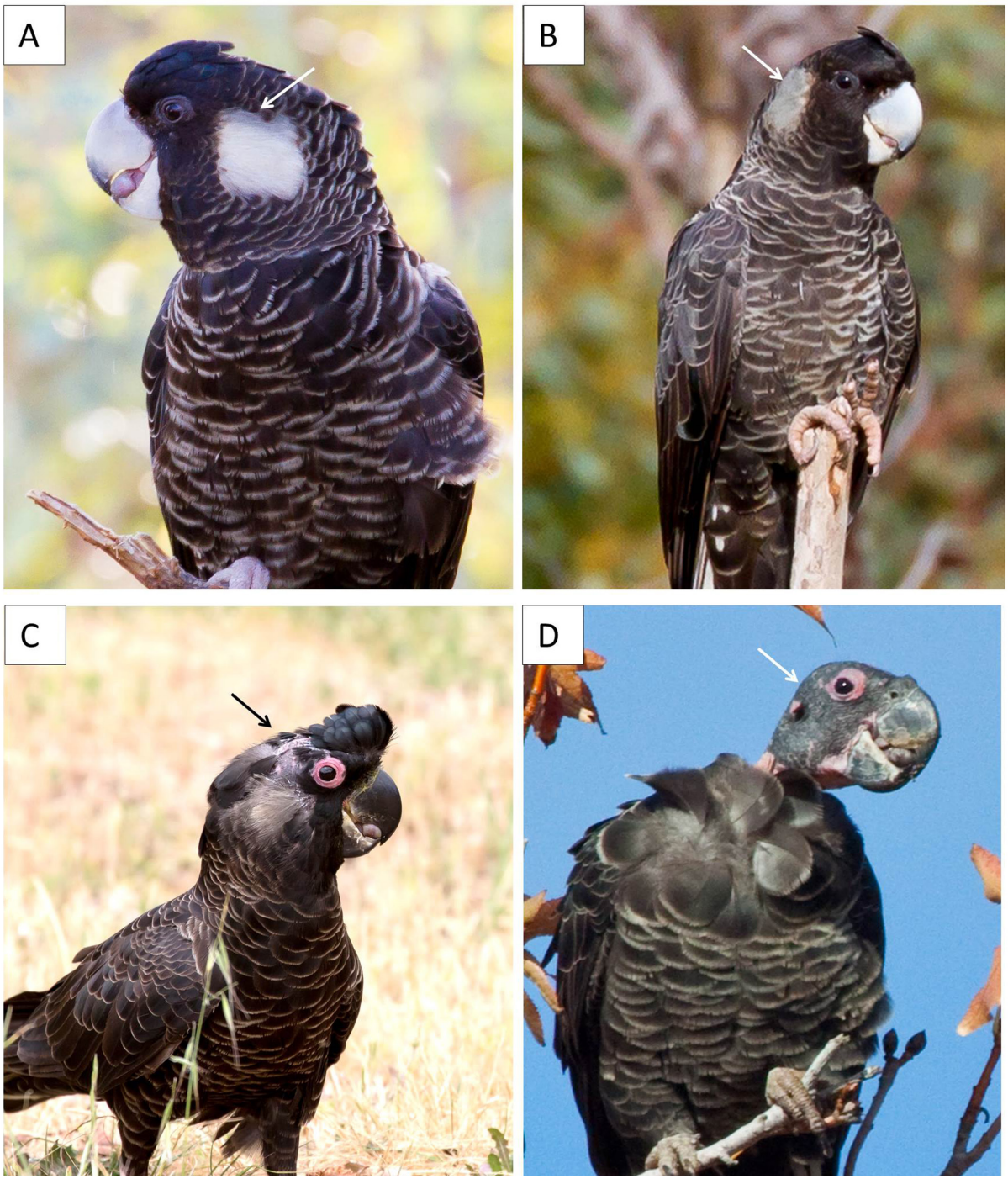

Figure 4. Unusual ear covert patches and baldness in *C. latirostris* in the Perth metropolitan area. A: Female with a grey bar at the top of one ear covert. B: Female with grey ear covert patches. C: Partly bald male. D: Bald male.

Table 3. Results of preliminary aging tests on preserved *C. latirostris* from the Perth metropolitan area at the Western Australian Museum (WAM). Tails with distinctive black markings in subterminal panels were photographed and the patagium of 6 birds were sampled and analysed for the concentration of pentosidine to estimate the age of each bird.

WAM #	Age estimate (yr)	Notes
A36797	0.8	Half bars and large spots on several tail feathers.
A37193	1.0	Large spots/bars most feathers. One new feather (T6) not spotty.
A17073	3.8	Large irregular spots on T5 and T6, one side of tail.
A37183	4.0	A few spots on T5 and T6, one side of tail.
A36115	6.1	Spots on T5 and T6 feathers. One new feather (T5) with spots.
A34484	8.1	Faint bar on one T6.

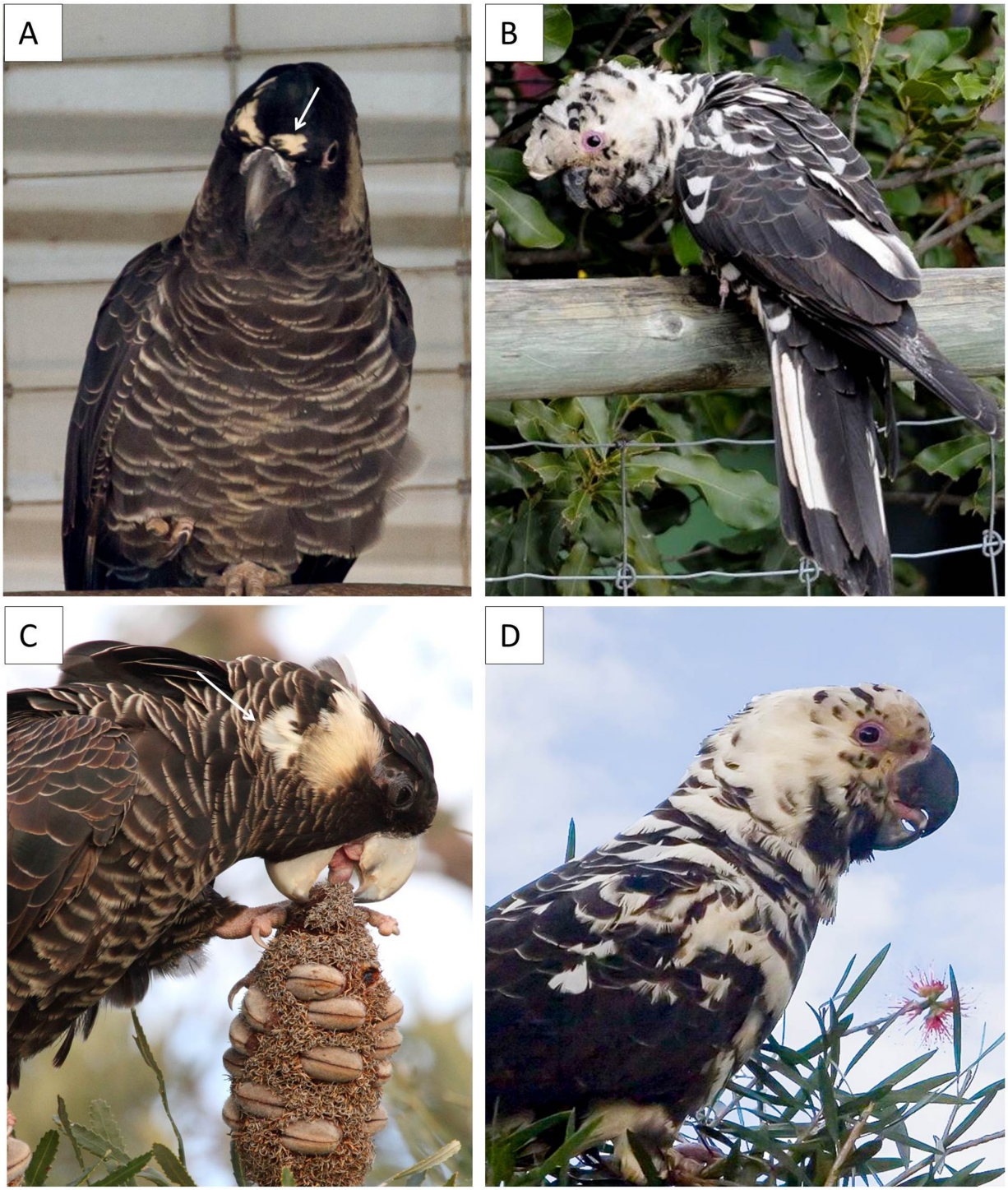

Figure 5. Distinctive markings on the heads and upper bodies of C. latirostris in the Perth metropolitan area. A: Male with white feathers on his head at Kaarakin Black Cockatoo Conservation Centre. B: Male with large areas of white (photo by Tony Kirkby 2009). C: Female with small area of white below the ear covert and on back of head and reduced toenail. D: Male with extensive white on head and chest (photo by Roger Severn 2007).

Both sexes – Baldness.

Field observations revealed varying degrees of baldness for both male and female C. *latirostris* in the Perth metropolitan area (Fig. 4C, D). Baldness varied in extent, from missing feathers on the lores creating a bald area between the mandible and the eye, to missing a strip of feathers from behind the eye, across the top of the head to the opposite eye (Fig. 4C), and lastly, to the head being completely bald. A completely bald male (Fig. 4D) was photographed over two years and showed no sign of re-growing the missing feathers. His baldness enabled him to be readily distinguished at great distance based on his silhouette while perched or flying. One partly bald male was observed feeding a female during the breeding season, suggesting that the pair was nesting. This bird was also photographed over 2 years, and black spots on his periophthalmic ring did not change over the course of 12 months.

Other features

The extent of white panels on the UTC varied between individuals (Figs. 2a and 2b), but their presence on many *C. latirostris* required other distinctive markings to be noted to identify individuals uniquely, and their persistence in the long term is unknown. Some individuals with unusually extensive markings on the UTC have been observed (Fig. 2aC), and it may be possible to identify these individuals within a study population. UTC panels were symmetrical on both sides of the tail (unless feathers were missing) and varied in thickness, brightness, and the number of feathers with white panels. No white panels were observed on male UTC in the wild Mundaring population; however, over half (51.9%) of preserved adult males had panels on the UTC (Table 4). Prevalence of panels on UTC of preserved specimens was similar for males and females as well as adults and juveniles (Fig. 6).

Healed injuries such as missing toes, damage to the cere, reduced toenails (Fig. 5C), misaligned legs or other injuries from past breakages can also assist identification of individuals, and most are long term characteristics. Other, shorter term damage, such as notched tail feathers and stained feathers can sometimes be used. In addition, several other features have been observed, which cannot be used for identification on their own, but can be used in conjunction with other distinctive markings to identify individuals. For example, while the left foot is typically used to hold food during feeding, occasionally an individual is "right footed". This is likely to be a long-term characteristic, but not exclusive to that individual.

The extent of white edging on the neck and chest feathers also varied, and was occasionally extensive (Fig 2aD), but was typically not distinctive enough to use as a determining mark. On some birds a small white "epaulet" formed on the shoulder, caused by longer white fringes on the feathers in that area. In addition, the tips of tail feathers may be broad or "pointed", and the width and length of tail feathers varies between individuals, with fledglings having shorter tails than adults (Saunders 1982). Apart from extreme examples, these features are not helpful for identification of individuals in the field, unless they are used in conjunction with other distinctive characteristics.

Discussion

We report for the first time the prevalence of markings on the subterminal tail panels of *C. latirostris*. These black spots and bars formed unique patterns and were often the most obvious characteristic for identifying individual *C. latirostris*. The extent of the markings appeared to be correlated with the sex and age of individuals, with our data suggesting that as the birds age the prevalence of markings reduces. However, the degree to which markings are retained in successive moults is not known. We found that subterminal tail panel markings occur most commonly in immature females, followed by adult females, immature males and adult males (Fig. 1). Tail markings are useful short-term characteristics for identifying individuals in the field, and where individuals are regularly observed, the re-growth of tail feathers may be monitored for changes in markings. This would potentially permit the ongoing identification of individuals with markings.

The black subterminal tail panel markings we have reported in this study are pigmented areas and are not caused by stress. The markings are distinctly different to the "feather breaks" or "stress marks" reported elsewhere, for example in Metz and Zimmermann (2011).

We found that a variety of distinctive markings can be used to identify individual *C. latirostris*, with markings on the head and T6 tail feathers the most readily observed features in the field. Distinctive markings include black spots and bars in subterminal tail panels, baldness, grey or gold ear covert patches on females, yellowish subterminal panels and atypical white feathers on the head or body. Some of these characteristics are likely to be long-term (Table 2). Other markings are more subtle, and include

Table 4. The percentage of *C. latirostris* museum specimens from WAM and ANWC that have undertail coverts (UTC) with white panels, by sex and maturity, where known. nk = not known.

		WAM	ANWC	Totals All	% All
Adult female	Total	9	26	35	
	With UTC panels	6	9	15	42.9%
Female maturity nk	Total	8			
	With UTC panels	3			37.5%
Adult male	Total	15	12	27	
	With UTC panels	7	7	14	51.9%
Male maturity nk	Total	7			
	With UTC panels	1			14.3%
Immature female	Total	9	20	29	
	With UTC panels	1	10	11	37.9%
Immature male	Total	3	13	16	
	With UTC panels	2	4	6	37.5%
Unkown sex	Total	7		7	
	With UTC panels	1		1	14.3%

black marks on female upper mandibles and white panels in the UTC. It may also be possible to identify mature male *C. latirostris* based on the pattern of black spots in their periophthalmic rings, as for Hyacinth Macaws (Munn 2006), however, this requires further investigation.

Several of the less unique features can often be used together or in combination with unique markings such as spotting/barring patterns on the subterminal panels to identify individuals. For example, adult *C. lathami* have variable degrees of panels in their UTC, which can be used in combination with the size and colour of upperwing covert spots to identify individuals within breeding seasons, and sometimes beyond (pers. comm. L. Pedler).

It should be noted that in the field UTC with panels are not always visible due to the arrangement of surrounding feathers and the position of the wings. In addition, perceptions of variations in colour can change depending on shadows and lighting quality and conditions, and colour may be reflected from nearby surfaces. The ear covert patches may also become dirty if the bird has been using its bill to move nesting material or excavate invertebrate larvae.

Greater ease of re-sighting individuals, with both obvious and subtle distinctive markings, was achieved for the Mundaring population as birds regularly returned to the same location to drink and attend to young, enabling them to be photographed many times. Re-sightings of individuals with distinctive markings in the field required considerable effort due to the mobility of the species during the non-breeding season, when birds are not returning regularly to a nest. Individuals with more obvious bars and spotting on the subterminal tail panels, particularly the T6 tail feathers, achieved the most re-sightings (Appendix 2).

Subterminal tail panel markings may be evolutionary relics, and this is further supported by our observations of yellowish subterminal panels and "old gold" ear covert patches on several female *C. latirostris* (Fig. 3). Both white-tailed black cockatoo species in Western Australia, *C. latirostris* and *C. baudinii,* are closely related to *C. funereus* from eastern Australia (Saunders 1978; White *et al.* 2011) from a common ancestor with *C. banksii* and *C. lathami* (White *et al.* 2011). *C. funereus* have yellow ear coverts and subterminal tail panels, with females and immature birds showing more heavily spotted subterminal panels than adult males (Courtney 1986b; Forshaw 2002). The red tail panels of female and immature *C. banksii* and *C. lathami* are typically heavily barred, with immature males gradually losing markings with each moult (Forshaw 2002; Murdoch 2008).

However, individual variation in barred patterns does exist, with some adult female *C. lathami* lacking apparent barring on their tails, and some having predominantly yellow-orange barred tails (Garnett *et al.* 1999). It is now thought likely that the tail barring of female *C. lathami* also gradually reduces with age, but this is not well understood (pers. comm. L. Pedler). This pattern is consistent with our observations of 53.1% of immature female *C. latirostris* having subterminal tail panel markings, compared to 28.6% of mature females, and 12.5% of immature males compared to 5.0% of adult males.

In an observation similar to ours of two female *C. latirostris* with yellowish tail feathers, Possingham (1986) reported an orange wash on the tail of a single *C. funereus* nestling at Eyre Peninsula. This colouration was not previously recorded for *C. funereus* and complements our data, which also includes another two female *C. latirostris* with "old gold" ear covert patches and edges to feathers. Again, this suggests some members of these two species are "throwbacks" to a common ancestor with *C. banksii* and *C. lathami*. Interestingly, in our study both female *C. latirostris* with yellowish subterminal panels also had black spots or bars on the yellow feathers (Fig. 3B, C), but had typical white ear covert patches. One of these females lost both the fine black spots and the yellow colouration of the subterminal tail panels in a subsequent moult.

Higgins (1999) states that a little speckling may be present in the subterminal panels of both adult and juvenile *C. latirostris*, but does not mention half bars or bars, or reduction of these markings with age. Forshaw (2002) states that juvenile *C. latirostris* have the same appearance as females "...but with narrower, slightly shorter flight and tail feathers...narrower white tail-band sometimes with irregular dark blotches, more prevalent on inner webs of tail-feathers..." Other references do not report changes in *C. latirostris* plumage with age (Higgins 1999; Johnstone and Storr 1998). Indeed, del Hoyo *et al.* (1997) states that there is no immature *C. latirostris* plumage. Courtney (1986a) states that the *C. latirostris* juveniles have unbarred and unmarked subterminal tail panels, as do adults, but notes that subterminal panels of nestling *C. funereus* are heavily barred with wave-like markings.

Baldness was another identifying feature of some *C. latirostris* that was readily observed in the field. Although an unusual feature, we believe that it persisted in at least one individual over two years. Baldness occurred on both sexes and was confined to the head in all cases we observed, with other feathers appearing normal. The cause of baldness is not known: it may be due to parasites, disease, excessive allopreening or mutations. Beak and Feather Disease Virus has been detected in *C. latirostris* nestlings and the clinical impact appears to be small; there have been no confirmed clinical cases in wild adults (pers. comm. Simone Vitali, Perth Zoo). A scat sample collected from a wild female with a partially bald head tested negative for the virus, however, faecal material is not a reliable method for such diagnosis (pers. obs. CG). For balding *C. latirostris* with more than the lores lacking feathers, part, or all, of the crest was missing. Yet in one case a partly bald male was displaying breeding behaviour by feeding a female, so it seems that the "disability" in communication created by the partial or total lack of a crest does not prevent reproduction in *C. latirostris*.

During this study white patches were photographed on the heads of two *C. latirostris*, a male and a female, and two other males with extensive white predominantly on the upper parts of their bodies have been photographed in the Mundaring and Perth regions by others (Fig. 5). Atypical white feathers are most likely a result of leucism, an inheritable genetic mutation that results in loss of melanin from some or all feathers, whilst soft parts, including eyes, remain normally coloured (Van Grouw 2006; Guay et al.

2012). Such variations in plumage are readily observed, but are also rare in the populations studied (e.g., only one individual with white patches observed in 540 hours spent following flocks in the field). It is possible that *C. latirostris* with unusually large areas of white are more heavily predated than typically marked individuals, in a similar manner to birds fitted with patagial tags (Saunders 1988).

Varying amounts of white on the body and head of individual *C. latirostris* have been reported previously. Johnstone RE, Johnstone C and Kirkby T (*in litt.*) repeatedly sighted a male with white feathers on its head, and used these observations to state that "It is apparent that flocks move over fairly large parts of the southern Swan Coastal Plain in search of food e.g. a leucistic (piebald) male was photographed at Leeming, Kelmscott and Keysbrook, giving an indication of local movements". Mead-Hunter (2005) observed a leucistic *C. latirostris* at South Lake (next to Bibra Lake) and Howatt (2009) reported that a piebald *C. latirostris* had been observed a number of times and photographed at Bridgetown and Blackwood River, and include a photograph of what appears to be a male in flight. Atypical white feathers on an individual are the most distinctive identifying characteristic, being easily observed, long term and unique.

In our study black lines were found to persist on the upper mandibles of two female *C. latirostris* in the Mundaring population for several years, allowing nest hollow fidelity by these individuals to be determined. For one female the black line was easily observed, and because it grew continuously from the base of the upper mandible, the line was likely to be a permanent characteristic. As noted above, other variations in markings also occur. Variations such as black extending up the rachis of tail feathers and unusually shaped subterminal tail panels may not be maintained in subsequent moults, as similar types of variation in *C. lathami* have changed over subsequent years (pers. comm. L. Pedler).

In conclusion, this study examined wild *C. latirostris* and museum specimens, providing new data on variations in markings, their prevalence in each sex, and their usefulness for identifying individuals in the field. These observations showed that tail panel markings were sometimes associated with mature breeding birds. However, museum specimens and age testing indicated that the most heavily marked tails were typically associated with immature females, suggesting the marks are evolutionary relics.

The seven types of variation in markings we found may sometimes be combined to identify individuals, although markings in subterminal tail panels may be used in isolation. Using these techniques, we found that some individuals could be re-sighted repeatedly in the field. This permitted the authors to gain a better understanding of breeding patterns and the movements and group associations of individuals during the non-breeding season.

In addition, we were able to observe competition for nest hollows and nest hollow fidelity by individual females, similar nesting times between years for two females, and the return of both male and female immature birds to their breeding site, in the company of their parents. This shows that immature birds have knowledge of their natal area, permitting them to return there to breed as adults, as demonstrated by Saunders and Ingram (1998). We also regularly observed females and their associated males inspecting nestlings that were not their own during the absence of the parents. A similar observation was made for males of *C. lathami* (Garnett *et al.* 1999). Future observations of *C. latirostris* will enable the authors to monitor the long term breeding success of particular pairs, and potentially the return of fledglings to breed in their natal area. The information in this study may also assist the research and management of other black cockatoo species.

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APPENDIX 1

Appendix 1. Results for spots and bars on the tail panels of preserved specimens of *C. latirostris* at CSIRO Australian National Wildlife Collection Canberra and the Western Australian Museum. M = male, F = female.

Code	Maturity	Sex	Markings	Collection location	Comments
Fanned tails at CSIRO Australian National Wildlife Collection Canberra, all specimens from the Perth metropolitan area.					
G46/70	Adult	M	No	Gnangara	Grey marks distributed. Spotting at base of T6
G47/70	Adult	M	No	Gnangara	Spotting at base of T6
G43/70	Adult	M	No	Gnangara	
G35/70	Adult	M	No	Gnangara	
G31/70	Adult	M	No	Gnangara	
G29/70	Adult	M	No	Gnangara	
G22/70	Adult	M	No	Gnangara	
G18/70	Adult	M	No	Gnangara	
M23/70	Adult	M	No	Mundaring	
No ID	Adult	M	No	Gnangara	
M14/70	Adult	M	No		Grey marks distributed
M7/70	Adult	M	No	Mundaring	White panels small with thick rachis
M2/70	Adult	M	No	Mundaring	Grey marks distributed
G7/70	Adult	M	No	Gnangara	Grey marks distributed, white panels smaller, spotting at base
G70/70	Adult	M	Yes	Gnangara	1 broad band, near base
G50/70	Adult	M	No	Gnangara	
G49/70	Adult	M	No	Gnangara	
G30/70	Adult	M	No	Gnangara	Grey marks distributed
G20/70	Adult	M	No	Gnangara	
G23/70	Adult	M	Yes	Gnangara	Several black spots. Spotting at base
G11/70	Adult	M	No	Gnangara	Spotting at base
M8/70	Adult	M	No	Mundaring	Grey marks distributed
M11/70	Adult	M	No	Mundaring	Spots near base of 1 T6
G11/70	Adult	M	No		Grey marks distributed, not many
CSIRO males					24 Total. 2 with marks
CSIRO % males with spots/bars					8.30%
M19/70	Adult	F	No	Mundaring	
G8/70	Adult	F	No	Gnangara	
G37/70	Adult	F	No	Gnangara	
G72/70	Adult	F	No	Gnangara	
G39/70	Adult	F	No	Gnangara	
G16/70	Adult	F	No	Gnangara	Grey marks distributed
G121/70	Adult	F	No	Gnangara	

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Code	Maturity	Sex	Markings	Collection location	Comments
G25/70	Adult	F	No	Gnangara	
G62/70	Adult	F	No	Gnangara	
G54/70	Adult	F	No	Gnangara	Few grown tail feathers
S5/70	Adult	F	Yes	Somerville	1 bar on each of T6. Many grey marks
G65/70	Adult	F	No	Gnangara	
G28/70	Adult	F	No	Gnangara	
G58/70	Adult	F	No	Gnangara	
G32/70	Adult	F	Yes	Gnangara	1 small spot
M6/70	Adult	F	No	Mundaring	Grey in T1 feather
G13/70	Adult	F	No	Gnangara	Stained
G68/70	Adult	F	Yes	Gnangara	Several small spots
G44/70	Adult	F	No	Gnangara	
G61/70	Adult	F	Yes	Gnangara	Large spots on T6 feathers each side
G66/70	Adult	F	Yes	Gnangara	Small spots on several feathers
M6/70	Adult	F	No	Mundaring	
G36/70	Adult	F	No	Gnangara	
G67/70	Adult	F	No	Gnangara	Old feathers, heavily marked with grey
S3/70	Adult	F	Yes	Somerville	Spots on one inner web, 1 vertical line
S2/70	Adult	F	No	Somerville	
CSIRO females					26 Total. 6 with marks
CSIRO % females with spots/bars					23.1%
G5/70	Immature	M	No	Gnangara	Grey marks,
M4/70	Immature	M	No	Mundaring	A few grey marks
M5/70	Immature	M	No	Mundaring	Grey marks. Small feathers next to T1
S4/70	Immature	M	No	Somerville	Grey marks
G10/70	Immature	M	No	Gnangara	Grey marks
G19/70	Immature	M	No	Gnangara	Grey marks. Long black lines on 2 feathers, are not on both sides of the feather.
G3/70	Immature	M	No	Gnangara	
G6/70	Immature	M	No	Gnangara	Grey marks
G21/70	Immature	M	No	Gnangara	Grey marks
G55/70	Immature	M	Yes	Gnangara	Thick bars, 3 rows on T6 feathers. Heavy spots on other feathers.
G63/70	Immature	M	Yes	Gnangara	Bar, spots on outer feathers
G60/70	Immature	M	No	Gnangara	Grey marks
G69/70	Immature	M	No	Gnangara	Grey marks.
CSIRO immature males					13 Total. 2 with marks.
CSIRO % immature males with spots/bars					15.4%
G51/70	Immature	F	No	Gnangara	
G27/70	Immature	F	No	Gnangara	

APPENDIX 1

Code	Maturity	Sex	Markings	Collection location	Comments
G9/70	Immature	F	Yes	Gnangara	Vertical bar on T2 inner web. Half of other T2 inner web is black
G2/70	Immature	F	Yes	Gnangara	Fine spots on T6 feathers
G15/70	Immature	F	Yes	Gnangara	Bars, 2 rows on some, heavy spots on all
M16/70	Immature	F	No	Mundaring	
G38/70	Immature	F	Yes	Gnangara	Fine spots on T6 feathers
M18/70	Immature	F	Yes	Mundaring	Spot on inner web, one feather
G64/70	Immature	F	Yes	Gnangara	Fine spots on multiple feathers
M10/70	Immature	F	No	Mundaring	
G1/70	Immature	F	Yes	Gnangara	1 small spot
G26/70	Immature	F	No	Gnangara	Small feathers next to T1
S1/70	Immature	F	No	Somerville	
G57/70	Immature	F	No	Gnangara	
G52/70	Immature	F	Yes	Gnangara	Small spot
M17/70	Immature	F	No	Mundaring	
G17/70	Immature	F	No	Gnangara	
G41/70	Immature	F	Yes	Gnangara	One line on outer panel
G24/70	Immature	F	Yes	Gnangara	Vertical line and large spot on inner web of T6 feather
G14/70	Immature	F	Yes	Gnangara	Many spots on all feathers
CSIRO immature females					20 Total. 11 with marks.
CSIRO % immature females with spots/bars					55.0%
G34/70	Unknown	Unknown	No	Gnangara	
No data SB	Unknown	Unknown	No		
No data I	Unknown	Unknown	No		
No date II	Unknown	Unknown	No		
No data III	Unknown	Unknown	No		
No data IV	Unknown	Unknown	No		
CSIRO unknown sex					6 Total. 0 with marks.
CSIRO % unknown sex with spots/bars					0.00%
Western Australian Museum (WAM) specimens				Collection location	
A18021	Adult	M	No	Mundaring	
A18022	Adult	M	No	Mundaring	
A18026	Adult	M	No	Mundaring	
A18033	Adult	M	No	Mundaring	
A18038	Adult	M	No	Somerville	
A37024	Adult	M	No	Gidgegannup	
A37025	Adult	M	No	Wilagee	
A37109	Adult	M	No	Munglinup	
A37104	Adult	M	No	Munglinup	
A37112	Adult	M	No	Munglinup	

APPENDIX I

Code	Maturity	Sex	Markings	Collection location	Comments
A37036	Adult	M	No	Capel	
A37110	Adult	M	No	Munglinup	
A37106	Adult	M	No	Munglinup	
A37105	Adult	M	No	Munglinup	
A37113	Adult	M	No	Munglinup	
A37175	Adult	M	No	Hopetoun	
WAM males					16 Total. 0 with marks.
WAM % males with spots/bars					0%
A11526	Unknown	M	No	Mundaring	
A38932	Unknown	M	No	Brigadoon	
A4717	Unknown	M	Yes	West Midland	Spots on multiple.
A25926	Unknown	M	No	Mogumber	
A38690	Unknown	M	No	Cottesloe	
A39002	Unknown	M	No	Claremont	
A39010	Unknown	M	No	City Beach	
A37188	Unknown	M	No	Hopetoun	
A37144	Unknown	M	No	Hopetoun	
A37145	Unknown	M	No	Hopetoun	
A37146	Unknown	M	No	Hopetoun	
A37147	Unknown	M	No	Hopetoun	
A37148	Unknown	M	No	Hopetoun	
A37149	Unknown	M	No	Hopetoun	
A37150	Unknown	M	No	Hopetoun	
A37151	Unknown	M	No	Hopetoun	
A37152	Unknown	M	No	Hopetoun	
A37153	Unknown	M	No	Hopetoun	
A37154	Unknown	M	No	Hopetoun	
A37156	Unknown	M	No	Hopetoun	
A37157	Unknown	M	No	Hopetoun	
A37158	Unknown	M	No	Hopetoun	
A37159	Unknown	M	No	Hopetoun	1 half brown feather, inner web, shaded lighter to outside.
WAM males maturity nk					23 Total. 1 with marks.
WAM % males maturity nk with spots/bars					4.3%
A12465	Adult	F	Yes	Mt. Helena	One spot.
A15974	Adult	F	No	Mundaring	
A18029	Adult	F	No	Mundaring	
A18024	Adult	F	Yes	Mundaring	Several small spots.
A18025	Adult	F	No	Stoneville	
A18031	Adult	F	Yes	Mundaring	Couple small spots.
A18037	Adult	F	No	Kinbrup	
A36944	Adult	F	No	Ocean Farms	
A37035	Adult	F	Yes	Capel	Multiple spots on most.
A37184	Adult	F	Yes	Hopetoun	Small spot and large spot.
A37185	Adult	F	Yes	Hopetoun	One small spot.
A37189	Adult	F	Yes	Hopetoun	Single spot.

APPENDIX 1

Code	Maturity	Sex	Markings	Collection location	Comments
A37191	Adult	F	Yes	Hopetoun	Several small spots.
A37192	Adult	F	No	Hopetoun	
A37194	Adult	F	No	Hopetoun	
A37171	Adult	F	No	Hopetoun	
A37172	Adult	F	No	Hopetoun	
A37174	Adult	F	No	Hopetoun	
A37176	Adult	F	No	Hopetoun	
A37177	Adult	F	Yes	Hopetoun	Several small spots.
A37178	Adult	F	Yes	Hopetoun	Spots on several feathers.
A37179	Adult	F	No	Hopetoun	
A37180	Adult	F	No	Hopetoun	
A37181	Adult	F	Yes	Hopetoun	One small spot.
A37162	Adult	F	No	Hopetoun	
A37163	Adult	F	No	Hopetoun	T2 feather brown mottled.
A37166	Adult	F	No	Hopetoun	
A37127	Adult	F	Yes	Hopetoun	One spot on T6.
A37128	Adult	F	No	Hopetoun	
A37129	Adult	F	No	Hopetoun	
A37130	Adult	F	No	Hopetoun	
A37131	Adult	F	No	Hopetoun	
A37134	Adult	F	No	Hopetoun	
A37138	Adult	F	No	Hopetoun	
A37139	Adult	F	No	Hopetoun	
A37141	Adult	F	No	Hopetoun	
A37142	Adult	F	No	Hopetoun	
WAM adult females					37 Total. 12 with marks.
WAM % adult females with spots/bars					32.4%
A37137	unknown	F	No	Hopetoun	
A37136	unknown	F	Yes	Hopetoun	Bars on all feathers. Very small ovaries.
A37133	unknown	F	No	Hopetoun	
A35688	unknown	F	No	Gooseberry Hill	
A34838	unknown	F	Yes	Wilson	Extensive bars, spots, all. Not specified as adult.
A27670	unknown	F	No	Lower King	
A37240	unknown	F	No	Bibra Lake	
A18597	unknown	F	No	Wanneroo	
A6554	unknown	F	No	Kakerin	
A38754	unknown	F	Yes	Cockburn	Multiple spots. Inner web of one feather grey/brown.
A39001	unknown	F	Yes	Westminster	Several spots, extension of black up rachis. Yellowish ear covert.
A37186	unknown	F	No	Hopetoun	
A37187	unknown	F	Yes	Hopetoun	Few small spots on yellowish feather.
A37193	unknown	F	Yes	Hopetoun	Many large spots. One new feather with spots.

APPENDIX I

Code	Maturity	Sex	Markings	Collection location	Comments
A37167	unknown	F	No	Hopetoun	T2 feathers black, only a small bit of white.
A37170	unknown	F	Yes	Hopetoun	Barred old feathers. New feather one small spot, other new feathers none.
A37165	unknown	F	No	Hopetoun	
WAM females					17 Total. 7 with marks.
WAM % females with spots/bars					41.2%
A18035	Immature	M	No	Byford	
A18034	Immature	M	No	Mundaring	
A18036	Immature	M	No	CSIRO Helena Valley	Captive
WAM immature males					3 Total. 0 with marks.
WAM % immature males with spots/bars					0.0%
A37140	Immature	F	Yes	Hopetoun	Bars, spots on most.
A6400	Immature	F	No	Hopetoun	
A12464	Immature	F	Yes	Mt Helena	Many spots.
A18023	Immature	F	Yes	Kalamunda	One small spot.
A15975	Immature	F	No	Gnangarra	
A18020	Immature	F	No	Gnangarra	
A18028	Immature	F	No	Mundaring	
A18030	Immature	F	No	Byford	
A18032	Immature	F	No	Byford	
A34994	Immature	F	Yes	Bentley	One spot.
A37107	Immature	F	Yes	Munglinup	Heavy barring on all feathers
A37108	Immature	F	Yes	Munglinup	Multiple spots
WAM immature females					12 Total. 6 with marks.
WAM % immature females with spots/bars					50.0%
A17073	Unknown	Unknown	Yes	Pinjarra	Female? Spots on multiple feathers.
A6563	Unknown	Unknown	Yes	North Bannister	Female? Several small spots.
A9340	Unknown	Unknown	No	Jurien Bay	Male?
A28018	Unknown	Unknown	No	Kings Park Perth	
A34484	Unknown	Unknown	Yes	South West	Small bar and spot, unusual extension of black up rachis.
A35618	Unknown	Unknown	No	Chidlow	
A37164	Unknown	Unknown	Yes	Hopetoun	Bars on all.
A37182	Unknown	Unknown	Yes	Hopetoun	One small spot.
A37249	Unknown	Unknown	No	Hopetoun	
A37169	Unknown	Unknown	No	Hopetoun	
A37160	Unknown	Unknown	No	Hopetoun	
A37161	Unknown	Unknown	No	Hopetoun	
A37155	Unknown	Unknown	No	Hopetoun	Immature?
A37132	Unknown	Unknown	Yes	Hopetoun	Couple of small spots. Male?
A37002	Unknown	Unknown	Yes	Cheynes	Spots.
WAM immature females					15 Total. 7 with marks.
WAM % immature females with spots/bars					46.7%

APPENDIX 2

Appendix 2. Field observations of wild *C. latirostris* in the Perth metropolitan area with spots or bars in the white tail panels. "Imm" = immature, based on behaviour and posture observed in the field.

Bird	Tail marking description for T6	Imm?	First sighted	Last sighted	Locations sighted (suburbs)	# days monitored	# days seen	# sightings	Comments
1	Two bars and a third less distinct bar of spots above		22/03/2013	16/07/2013	Canning Vale, Forrestfield	116	3	4	
2	Two spotty bars and a third less distinct bars of spots above		25/06/2013	25/06/2013	Cloverdale	1	1	1	
3	Two bars, lower bar solid		6/05/2013	6/05/2013	Beckenham	1	1	1	
4	Half-bar extending into middle of feather and spotted bar above		14/05/2013	1/07/2013	Bayswater, Como, Ashfield	48	3	3	
5	Comma shaped mark on T6, various barring and spots of inner tail feathers		30/05/2013	16/07/2013	Bentley, Como, Forrestfield	47	3	3	Possibly re-growing feather without markings
6	Single strong angled solid bar near distal end of feather		4/07/2013	4/07/2013	Bayswater	1	1	1	
7	Single strong solid bar in middle of T6 forming oval of white below		2/04/2013	16/08/2013	Kensington, Beckenham, Cloverdale, Forrestfield, The Vines	136	5	9	Re-growing feather without markings
8	Single strong bar near distal end of feather	Yes	1/03/2013	12/03/2013	Nedlands, West Perth	11	4	10	
9	Incomplete bar near distal end of feather forming circle of white below		16/08/2013	16/08/2013	Shenton Park	1	1	1	
10	Single strong bar near distal end of feather		18/06/2013	18/06/2013	The Vines	1	1	1	
11	Very wide strong band in upper middle quarter of feathers	Yes	3/05/2013	15/07/2013	Forrestfield, Beckenham, Banjup, Martin, Como, Gosnells, Harrisdale, High Wycombe	73	7	18	
12	Single spotty band near distal end of feather	Yes	12/03/2013	19/04/2013	Nedlands, Dalkeith, Shenton Park, Claremont	38	4	9	
13	Dash marking in centre of feathers near distal end of feather		5/08/2013	5/08/2013	Baldivis	1	1	1	